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MEETING REVIEW: THIRD CONFERENCE ON CLIMATE VARIATIONS AND SYMPOSIUM ON CONTEMPORARY CLIMATE: 1850–2100

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Program Chair

INTRODUCTION

The Third Conference on Climate Variations and Symposium on Contemporary Climate 1850–2100 was held in Los Angeles in coordination with the Annual Meeting of the American Meteorological Society and the International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. This combination of meetings attracted a large and interested audience throughout the week to hear more than one hundred papers and view about fifteen posters.

The climate variations conference was divided into two parts. The first part consisted of two special sessions reporting on the climate of 1984 (sponsored jointly with the national meeting) and discussing the atmospheric effects of a major nuclear exchange.

The second part, lasting three days, was entitled the Symposium on Contemporary Climate 1850–2100. This symposium comprised eight sessions reporting on various studies concerning climatic data and climatic change from the middle of the last century (when extensive observations began and prior to potential industrial-induced perturbations) forward to the end of the next century (when the climatic consequences of CO_2 and trace gas emissions are projected to be substantial).

This review of the special session on the Climatic Effects of Nuclear War and of the Symposium on Contemporary Climate has been prepared by the program and session chairs; they are listed by session. The review emphasizes a discussion of the major scientific issues and, as such, is not a description of every paper. The views and interpretations expressed are those of the session chairs. A volume of extended abstracts of the papers scheduled at the conference is available from AMS headquarters.

CLIMATIC EFFECTS OF NUCLEAR WAR (A. Hecht, chair)

C. Leovy of the University of Washington, substituting for P. Crutzen, opened the session with an overview of the just completed National Academy of Sciences assessment of the atmospheric consequences of a nuclear exchange, of which he was a major author. Leovy reviewed the assumptions used in making the climatic assessment, including especially how the amount of smoke and dust injections were derived. He emphasized the large uncertainties that are present in the calculations, but indicated that unless one or more assumptions are near the less severe end of their uncertainty range, or unless some

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mitigating effect has been overlooked, there is a clear possibility of significant climatic changes affecting a great portion of the Northern Hemisphere. Leovy emphasized the need for more research on atmospheric modeling and on developing better estimates of smoke generation.

R. Turco reviewed the various estimates of aerosols and gases that might be released in a nuclear exchange, indicating that emissions from both city and wildland fires could be substantial. Based on analyses of the components of the smoke term, he concluded that smoke injections of 100 million metric tonne or more from fires following a major exchange were quite plausible.

W. Cotton described a numerical experiment with a three-dimensional cloud model in which a strong surface heat flux (roughly equivalent in intensity to the Hamburg fire, but much larger in area) carried a large fraction of smoke particles from near the surface to above the tropopause. In the simulation, which assumed a conditionally unstable atmospheric sounding, a large cloud of condensed water was created, but only a few percent of the smoke particles were taken up in the droplets (nucleation scavenging, however, was not considered). The succeeding paper by L. Haselman, J. Penner and L. Edwards presented results of similar dynamical calculations assuming a range of fire intensities and other parameters, but with a standard atmosphere sounding and no scavenging. The results indicated the importance of fire intensity on the potential for smoke injection into the stratosphere, with fire intensities expected in forest and suburban areas creating plumes that rose only into the lower and middle troposphere.

Five other authors reported on the temperature response to large smoke injections based on general circulation model (GCM) studies. All of the papers indicated that, if large amounts of smoke survive scavenging in the fire plume and start to spread to global scales, Northern Hemisphere mid-latitude temperatures could decrease significantly. S. Schneider reported on NCAR simulations in which the smoke (absorption optical depth of 3) was assumed to have spread instantaneously over the mid-latitudes of the Northern Hemisphere and to then have remained fixed in location. The NCAR results indicate that summer continental temperatures could drop within a few days to a few weeks to below freezing, except near coastlines. They reported significantly larger temperature perturbations in summer than in winter. R. Cess, G. Potter and W. L. Gates described simulations at LLNL using the OSU/GCM in which smoke amount, optical properties, and vertical distribution were varied. Their studies indicated that the sharp cooling of the surface could only being after solar absorption by the smoke is sufficient to turn off the normal convective coupling of the surface and troposphere.

The three subsequent papers on climatic effects reported on studies in which the smoke was allowed to move. M. MacCracken and J. Walton, of LLNL, and R. Malone, L. Aver, G. Glatzmaier, M. Wood and O. Toon from Los Alamos National Laboratory (LANL) and NASA Ames Research Center reported on simulations of the effects of smoke injections from North America, Europe, and western Asia, while V. Aleksandrov of the Soviet Academy of Sciences started with the smoke spread evenly around the Northern Hemisphere mid-latitudes. In each of these studies, the heated smoke dramatically altered the normal summer Hadley circulation, leading to rapid spreading of the smoke to the Southern Hemisphere at upper atmospheric levels. In the LLNL results, this led to a thinning of the smoke in the Northern Hemisphere and a modest recovery of temperatures from their very sharp (25–35°C) initial reduction in mid-continental regions. Unevenness in the smoke distribution during the first few weeks did allow short-term temperature recovery in some regions, but within a few weeks the effects of the patchiness had largely disappeared, except for an apparent circulation-induced accumulation of smoke over the Asian continent. The LANL results indicated that the smoke could rise well into the stratosphere and that this lofting could induce stabilization of the upper atmosphere that could lengthen the atmospheric lifetimes of particles from normal values of a week or two to several months or more. The Soviet simulations showed that significant temperature changes in low latitudes and the Southern Hemisphere could occur if very large amounts of smoke (several times the baseline value used in of the other studies) were to be injected and spread to the Southern Hemisphere.

A. Hecht of the National Climate Program Office concluded the session with a brief status report on the efforts to develop an interagency plan for research on this topic. This research plan was released February 5, 1985, and copies are available from the Executive Office of the President, Office of Science and Technology Policy, Washington, DC 20506.

SYMPOSIUM ON CONTEMPORARY CLIMATE 1850 2100

Session 1: The Challenge of Understanding Contemporary Climate

To increase confidence in projection of future climatic conditions, it is important to be able to explain and understand past variations. This symposium was convened to provide an opportunity to address the status of efforts to understand the variations and changes in climate that have been experienced since 1850 and to review the status of efforts to look forward more than a century to 2100. In opening the symposium, M. MacCracken, chair of the AMS Committee on Climate Variations, described the apparent contradiction in observational and modeling studies of the warming expected from rising CO_2 and trace gas concentrations. Observational studies indicate that hemispheric average temperatures have increased only about 0.5°C since 1850 whereas simple logarithmic interpolation of recent equilibrium CO_2 doubling experiments (which indicate a warming of about 3–4.5°C) would require an equilibrium warming of more than 1°C; past increases in trace gas concentrations would raise this value further. The Symposium's seven subsequent sessions were each intended to address a class of arguments (and related issues) that have been put forth in an attempt to reconcile observations and model results.

Session 2: Are the observational records of temperature and other variables adequate? Could there be biases, a lack of areal coverage, or other problems that make the records suspect?

Session 3: Can changes in the climatic record be detected with confidence? Do we have the needed statistical tools and length of record to determine the difference between changes and fluctuations?

Session 4: Could perturbations by factors other than CO_2 be obscuring the CO_2 signal? Could changes in solar insolation or in volcanic aerosol loading be causing a cooling that is counteracting the projected CO_2-induced warming?

Session 5: Are parameterizations in models adequate to make climatic projections? Could some negative feedback processes have been omitted from the models?

Session 6: How well do models represent internal climate oscillations, for example as a result of sea and/or land surface perturbations or of ocean circulation changes?

Session 7: How sensitive are climate models to changes in CO_2 concentration? Does inclusion of a better representation of the ocean affect calculated climate sensitivity?

Session 8: Are existing methods adequate to derive estimates of time-dependent temperature change from simulations of estimates of equilibrium CO_2 sensitivity. To what extent can oceanic heat capacity and circulation reduce or delay the rate of CO_2-induced warming? What can analysis of past climate conditions and trends tell us about the future climate?

A poster session was also held that presented results on studies of climatic change in particular regions and other specific aspects of the questions discussed in the various sessions. These papers are considered here as they relate to the particular session topics.

Session 2: The Contemporary Climate Record (H. F. Diaz and K. Hanson, co-chairs)

The session heard papers on newly extended hemispheric and global scale data sets available to the research community. Some analyses of these data sets were also presented. The analyses and discussions of the session were largely concerned with the influence of urbanization on temperature records, data editing procedures, and the effect of changing spatial coverage of land stations on estimates of hemispheric average temperature.

R. Bradley, H. Diaz, P. Jones and M. Kelly presented a paper describing expansion of the spatial coverage of long-term Northern Hemisphere land station data and extension of the Northern Hemisphere land temperature record back to 1851. D. Shea and W. Spangler have added to the World Monthly Surface Station Climatology (WMSSC) available at NCAR so that the global data set now includes over 4400 stations. S. Woodruff reported on the continued expansion of the Comprehensive Ocean-Atmosphere Data Set (COADS), which, after expansion and editing, includes over 70 million observations. The discussion of these papers was concerned with principles of editing these data sets.

The paper by P. Jones, M. Kelly, C. Goodess, R. Bradley and H. Diaz concluded that changes in spatial coverage of Northern Hemisphere land stations with time have had only small influences on estimates of Northern Hemisphere temperature anomalies. Based on these analyses, earlier estimates for the late 1800s may be too low by approximately 0.1°C. T. Karl, G. Kukla and J. Gavin showed evidence that the most significant temperature changes in the United States during the period 1941 to 1980 were a lower diurnal temperature range during all months of the year. However, in a companion study by the same group (presented by G. Kukla), the analysis of temperatures in North America during this time suggested a temperature increase of about 0.1°C per decade. Much of the discussion centered on temperature trends and their likely causes since the mid-1800s.

Session 3: Analysis of the Climate Record (T.M.L. Wigley and R. S. Bradley, co-chairs)

The papers presented in this session included discussion of temperature, pressure and precipitation records from the regional to global scale, plus two papers on river flow variations and two on tree-ring based climate reconstruction. Surface temperatures, both air and sea, were discussed by Kelly et al., S. Grotch, R. Chen and W. Gommell. Gommell's discussion of early work carried out in the 1960's under Bjerknes linked free air temperature anomalies to the influences of advection and underlying SST anomaly patterns and provided a backdrop for the more recent data analyses of the other three papers. In these, both Kelly et al. and Grotch alerted us to the changing spatial patterns of large-scale surface air temperature changes, complexities that must partly undermine the use of past data as an analog for the future, at least until our understanding of the causes of these changes is substantially improved. As an illustration of our lack of understanding on even the largest spatial scales, Kelly, et al. noted that land-based data from the Northern Hemisphere show a near step-like change around 1920. This item was discussed in greater detail by J. Rogers who linked the rapid changes to shifts in the position of the Icelandic Low. The land-based Northern Hemisphere average temperature appears to have been strongly influenced by these events in the North Atlantic, which in turn reflect circulation changes. Although the basic cause of these circulation changes is unknown, their regionality makes it unlikely that the rapid 1920's warming in the land-based record can be taken as evidence against larger-scale effects of increasing CO_2 levels, a point emphasized in a later session by H. Ellsaesser. No such rapid change is observed in the Northern Hemisphere mean sea surface or marine air temperature record of Folland et al. (*Nature, 310,* 670–673, 1984).

Parallel studies of circulation and temperature changes were the theme of three other papers. T. Moses, G. Kiladis, R. Barry, and H. Diaz looked in detail at years of extreme seasonal sea-level pressure anomalies ("pressure reversals") in the North Atlantic, while two papers by K. Mo and H. van Loon examined Southern Hemisphere data. In the latter papers, deficiencies in the gridded pressure data were circumvented by using station data. The extent of these deficiencies was highlighted by the analyses of atmospheric mass fluctuations in two papers by J. Christy and K. Trenberth. Their papers provided insights into the seasonal character of intra- and inter-hemispheric mass fluctuations.

A number of papers considered recent fluctuations in precipitation. D. Paolino and J. Shukla demonstrated the strong parallel between variations in monsoon rainfall over China and India. In both regions, particularly the latter, there is a noticeable influence of El Niño. Thus, the tree-ring based reconstructions of past El Niño frequencies (back to the early 17th century) by J. Lough and H. Fritts may have wide geographical significance and may provide a tropical complement to P. Mayes and G. Jacoby's attempt to use tree-ring data to reconstruct the Northern Hemisphere mean surface air temperature.

Studies by A. Douglas and P. Englehart and by C. Ropelewski and M. Halpert examined precipitation variations in the United States, with the latter authors considering fluctuations in Europe as well. Some interesting long-term trends were apparent in these data. On a smaller spatial scale, precipitation was just one of many climate parameters considered in S. Changnon's impact-oriented review of Illinois climate fluctuations. The impact of precipitation fluctuations on river flow in the Columbia and Colorado Rivers was the theme of a paper by D. Meko. Because riverflow is a relatively small residual from the difference of two large quantities (basin-mean precipitation and evapotranspiration), its variations can be much larger than those in either determining variable.

In terms of human impact, probably the most important papers were those dealing with Africa. S. Hameed and R. Currie showed that Nile River Flood levels have an 18.6 year periodicity, albeit a complex one. Even though this particular periodicity explains only a very small part of the variance, if such cyclic phenomena are real, it may have limited predictive value. More directly relevant, however, were the complementary analyses of recent rainfall variations by S. Nicholson and by P. Lamb. Both works showed that the Sahel drought, which was so well publicized in the early 1970's, has persisted to today, with 1983 and 1984 rainfall being as low as in any previous year. This event is now unprecedented in modern times, yet we still do not know its cause.

Deficiencies in our understanding of the causes of climatic change were apparent in many of the papers of this session. A handful of these papers demonstrated the importance of climate in the affairs of mankind. As data become more extensive, more reliable, and more carefully analyzed, the glimmers of physical insight that we saw here will become brighter lights. Progress is being made rapidly, but the problems, particularly those in Africa, are becoming more acute. Continued work is essential.

Session 4: Explaining Past Climatic Change (M. I. Hoffert and G. L. Potter, co-chairs)

While the preceding sessions dealt mainly with historical climate data, this was the first session to formally focus on theoretical interpretations. Theodore Von Karman once quipped, "when a new theory is presented no one believes it except the theorist; when new data is presented, everyone believes it, except the person who prepared the data". There is more than a kernel of truth to this observation, but the awareness of many types of uncertainties by the climate community seems somewhat greater than his statement implies, in that active controversies exist in both modeling and data analysis. Research on causes of climate change is presently in a state of flux While several provocative theories, and fragments of theories, of climate change were presented in this and later sessions, a central question is still whether conclusive tests against data can be designed to differentiate one theory from another.

The paper by A. Robock dealt with the possibility of detecting volcanic, carbon dioxide and El-Niño/Southern-Oscillation (ENSO) signals in surface air temperature records using a Soviet surface air temperature data set covering the period 1891 to 1981. The data were analyzed by examining volcanically-weighted temperature anomalies with respect to the previous 1, 2, 5 and 10 years. Potential ENSO signals were also studied by a similar procedure. In both cases there was some interannual persistence of anomalies, but signals of "internal" (ENSO) oscillations showed up more strongly in spatial patterns, while signals of "external" (volcanic) forcing showed up more strongly in zonal means.

A different type of radiative forcing was discussed in the paper by D. Wuebbles, A. Owens and C. Hales on trace gas influences on climate from 1850 to 1980. Using a time-dependent one-dimensional model, the authors' calculated that, in the radiatively important lower stratosphere and troposphere, ozone amounts should have increased by 2–3% and 5–8%, respectively, since 1850—in contrast to the naive expectation of an O_3 reduction by catalytic cycles in the stratosphere. They find a net equilibrium warming (i.e., no account was taken of the delaying effects of ocean thermal capacity) by all emissions of 1.0°C since 1850, of which 0.67°C is from CO_2 (1850 level of 270 ppmv), 0.21°C from CH_4, 0.02° from N_2O, and 0.08°C from chlorocarbons. The trace gas warming effect, therefore, enhanced the fossil fuel carbon dioxide greenhouse effect by approximately 50% over this period, and may be expected to become even more important in coming decades.

The role of the ocean in transient climatic changes was examined by R. Watts, who studied the influence of transient variations in thermohaline circulation on surface temperature variations. His model was a zero dimensional transient heat balance for the global ocean mixed layer coupled at the mixed layer/thermocline interface to a one-dimensional (vertically-resolved) upwelling-diffusion model for heat transfer within the deep ocean. When upwelling varies periodically about some mean value, as in Watts' model, the temperatures at the surface and different ocean depths also vary periodically in a manner that depends on the heat capacity, eddy diffusivity, mean upwelling rate and period of forcing. The author concluded that variations in deep water temperature reported by Roemish and Wunsch (*Nature*, *307*, 407, 1984) might have resulted from changes in deep water circulation, as opposed to "external" forcing by radiative perturbations, and that these might have been responsible for significant variations in global climate.

It is well appreciated by now that atmosphere/ocean interactions are major contributors to climatic variability. However, it is also a feature of most climate models that land surfaces affect climate sensitivity and response as well through such effects as snow albedo and soil moisture feedbacks. J. Walsh and W. Jasperson developed statistical correlations between surface air temperature, snow cover and soil moisture data over the United States and Eurasia. For snow, the correlations with temperature were longitude-dependent, and somewhat inconclusive. Statistically significant *negative* trends of the mean latitudinal extent of 2.5 cm snow coverage were found at 120°W, while a significant *positive* trend was found at 80°W. Correlations with soil moisture were variable as well, with a strong seasonality favoring the summer months. Such empirical studies could well lead, eventually, to more realistic depictions of land surface feedbacks in climate models.

H. Ellsaesser posed the question "Do the Recorded Data of the Past Century Indicate a CO_2 Warming?" According to some models, carbon dioxide added to the atmosphere thus far should already have produced a detectable warming in global temperature since 1880. Ellsaesser argued, however, that the response that has been seen is not temporally well-correlated with that which would be expected, unless climatological factors more potent than CO_2 have been generating 30–50 year cycles of warming and cooling that have obscured the carbon dioxide growth signal, and either the increase in hemispheric mean equilibrium temperature due to doubled CO_2 is no more than 1.5°C or an oceanic lag of at least 50 years has caused a delay in reaching a higher value closer to recent, higher estimates of the equilibrium warming temperature.

T. Bell and A. Abdulla presented an approach to spatial averaging and applying tests of statistical significance based on weighting factors as a means for maximizing the signal-to-noise ratio being developed in climate change detection studies. The technique was applied to a surface temperature data set covering four zones of the Northern Hemisphere. A GCM run was made which predicted that a surface cooling would result from the spring 1982 eruption of the El Chichon volcano, but the real climate system produced over a two sigma warming in the 1982–1983 period, presumably due to the ENSO event that began at almost the same time as the volcanic eruption. This result indicates the need for climate models that can predict such phenomena, as well as statistical analysis techniques to detect climatic variations in the data.

Session 5: Testing and Verification of Climate Models and their Parameterizations (W.L. Gates and R. Malone, co-chairs)

In addition to the assembly and analysis of observational data, an important part of climate research is the testing and verification of models designed to reproduce the contemporary climate and to project its change over the next century or so. The twelve papers presented in this session represented significant elements of such research.

The papers by M. Black and E. Pitcher and by Y. Sud, J. Shukla and Y. Mintz presented new evidence of the sensitivity of GCMs to the treatment of the surface moisture flux. Black and Pitcher found that replacement of the NCAR GCM's constant ground wetness parameter with substantially lower values over the normally arid regions of North Africa and North America generally raised the local surface temperature (via reduced evaporation), while lowering the local cloudiness and rainfall, especially in the summer. Using the GCM at the Goddard Laboratory for Atmospheric Sciences (GLAS) Sud et al. found that reducing the drag coefficient over all land surfaces to about 25% of its standard value (by reducing the land surface roughness) produced significant increases in the precipitation (and moisture convergence) in the Asian Inter-tropical Convergence Zone (ITCZ) in July. In view of this and other evidence, more attention should clearly be given to both the magnitude and geographical dependence of surface properties in GCMs. Other examples of model sensitivity to the treatment of the ocean and precipitation rate in simplified climate models were given in papers by H. Dalfes and S. Thompson and K. Bowman.

The persisting problem of adequately representing the effects of clouds and cumulus convection was considered in the context of one-dimensional models in papers by S.-C. Ou and K.-N. Liou and by R. Somerville. Ou and Liou confirmed that parameterized cumulus convection generally reduces the lower atmosphere's sensitivity to perturbations such as increased CO_2 and raises the sensitivity of the upper troposphere; this is an effect of special importance in the tropics. Somerville, on the other hand, examined the possibility that cloud optical thickness (which depends primarily on the liquid water content) may vary enough with temperature to provide a significant and as yet unappreciated feedback. Other things being equal, he finds that the surface warming induced by doubled CO_2 in a conventional radiative-convective model is reduced by about 50% when the cloud liquid water content (and hence the cloud optical thickness) is allowed to increase with the ambient temperature. Such a feedback should be tested in more comprehensive climate models, and further data on the variation of cloud optical properties should be collected.

D. Gutzler and P. Stone considered alternative parameterizations of the outgoing infrared flux in terms of the surface temperature, the fractional cloud cover, and the cloud top height. The parameterizations contained both linear and quadratic terms in these variables. Considering the latitudinal variation of outgoing infrared flux in a control climate simulation with the GCM at the Goddard Institute for Space Studies (GISS), they found that the best fit was obtained with linear terms alone. This fit also described well the latitudinal variation of this flux in a GCM simulation with a 2% increase in the solar constant. However, the best fit for the change in flux resulting from a change in the solar constant was obtained when the product of cloud top height and temperature was included in the fitting formula, although its inclusion had degraded the fit to the latitudinal variation in the control case. This apparent contradiction was not resolved, but the authors concluded that nonlinear terms should be included.

J. Gutowski, G. Molnar and W.-C. Wang considered the response of a climate model to alternative parameterizations of the meridional fluxes of sensible and latent heat. The two components of the heat flux were treated separately. After fitting them for the present climate, model calculations were made with doubled CO_2 and a 2% increase in the solar constant. For each perturbation, four cases were run with various constraints on the two components of the heat flux. Three of the cases gave approximately the same change in the total heat flux but significant differences in the equilibrium climate. It was concluded that the sensible and latent heat fluxes must be parameterized separately.

W. Sellers described the response of his 3-D climate model to a temporary reduction in the solar constant. His model is less complex than a GCM, and it appears to be less sensitive than GCMs to external perturbations. Sellers attributes this reduced sensitivity to the response of the model lapse rate to changes in the mean atmospheric temperature. This response is such that the effect of an external perturbation is maximized near the tropopause and minimized near the surface. Although the temporary reduction in the solar constant had no long-term effect on the model climate, Sellers noted a weakening of the tradewinds over the central Pacific. He conjectured that a major volcanic eruption could produce such a tradewind weakening and thereby trigger an El Niño event.

Comparisons of the cloudiness and radiation fields simulated by the UCLA GCM with observed distributions were presented in a pair of papers by D. Randall and Harshvardhan and by D. Short, D. Randall and Harshvardhan. These studies revealed that, although this 9-level model has relatively sophisticated cloud parameterization schemes, it simulates too little tropical cloudiness and too much cloudiness in high latitudes. Analysis of the cloud forcing of the atmospheric radiation budget showed that, in general, clouds act to cool the surface in the tropics (and in summer mid-latitudes), thereby suppressing convection, and to warm the surface in high latitudes (and in winter mid-latitudes). In comparison with observations made by NIMBUS 7 during the period June 1979 to May 1980, the model simulates a realistic seasonal variation of outgoing long-wave radiation, but underestimates the local reduction observed in the vicinity of the ITCZ, presumably due to the underestimate of tropical clouds mentioned in the first paper.

In the last paper of the session, M. Hoffert described model experiments to investigate mechanisms in the ocean that might lead to internal self-excited oscillations. This was motivated by observed interdecadal climate fluctuations that are not obviously attributable to variations in external forcings. A relationship between the upwelling velocity and the ocean surface temperature change was postulated that had a destabilizing linear dependence and stabilizing cubic dependence on the ocean surface temperature change. The resulting model then produced internal oscillations. When combined with observed CO_2 forcing, the observed trend in the global average surface temperature over the past century was reproduced with remarkable agreement. The authors noted, however, that such tuning does not provide a generally satisfactory physical explanation.

The models considered in this session's papers ranged from the simplest one-dimensional formulations to some of the more complex GCMs; in each, however, the model's sensitivity to the parameterization of subgrid-scale processes was shown to be significant and not well understood. This serves to underscore the often-repeated statement that the most critical (and difficult) problems in climate modeling are those relating to the parameterization of radiation, cloudiness and surface processes. In this sense the present papers are a representative sampling of the current state of the art.

Session 6: GCM Sensitivity to Surface Perturbations (K.E. Trenberth and R.C.J. Somerville)

There were eight GCM sensitivity studies presented in this session. Four of these used the NCAR CCM, three used the GLAS climate model and one the U.K. Meteorological Office GCM. One paper focused on the impact of SST anomalies in the tropical Atlantic Ocean, five papers concentrated on the various impacts of changes in Pacific Ocean SSTs, and two dealt with surface land properties.

O. Aragao concluded that, during the later stages of an El Niño, the atmospheric circulation changed in a way that led to a significant reduction in rainfall over northeast Brazil during the rainy season and that this was in keeping with observations. R. Malone, E. Pitcher, M. Blackman and J. Geisler suggested that the Pacific-North American (PNA) teleconnection pattern, associated with many El Niño events, is tied more to a barotropic unstable normal mode response rather than to direct tropical forcing and Rossby wave propagation in short term fluctuations. M. Blackmon, G. Bates and J. Geisler considered further experiments to address the same question. They removed the orography from the model, thereby changing the "basic state" and thus, presumably, the normal mode response. The results seemed to support the idea that the barotropic growth mechanism is more important for the PNA than direct Rossby wave propagation. However, they also noted that thermal rather than orographic forcing seems to play a dominant role in setting up the east-Asian jet in winter. Bates and Blackmon carried out model experiments for the Atlantic and found that SST anomalies appeared to influence the rainfall over Brazil. Results depended on where the SST anomaly was placed relative to the model ITCZ. When the anomaly was located under the ITCZ, the response was larger and only in this case was a significant extratropical response found in the North Atlantic.

Y. Sud and W. Smith investigated the roles of surface albedo, surface roughness and evapo-transpiration on the rainfall in the Indian monsoon. They infer that excessive land use that destroys vegetation, and lessens surface roughness, would weaken the monsoon. A paper by M. Wilson found that deforestation over South America, primarily through an albedo increase, caused locally significant reductions in rainfall, but that results depended strongly on the treatment of surface hydrology. Shukla and his colleagues gave two papers, presented by L. Marx and M. Fennessy, that considered predictability of the atmospheric circulation due to tropical and North Pacific SST anomalies with specific results for the 1982–83 El Niño event. Results are consistent with previous studies and indicate that the tropical circulation is much more reproducible and predictable on long time scales with fair success in simulating gross aspects of the 1982–83 event. In the extratropics, however, the response varied between different experiments and the signal was confounded by the noise.

Session 7: CO_2 and Climate Sensitivity Studies (S. Schneider and M. Riches, co-chairs)

There were a number of cross-cutting themes that emerged from this session. First, the two papers by J.F.B. Mitchell and by W.L. Gates and G. Potter emphasized that climatic response to external forcing can depend strongly on the control state. In particular, local precipitation perturbations arising from increased CO_2 are closely related to precipitating regions in the control runs. The best guide to interpreting the perturbation response of a model is both to analyze the control climate carefully (and compare it with observations) and to examine the physical mechanisms in the model that give rise to its perturbation response.

Another theme (Mitchell's second paper) was to recognize that climatic impact analysis requires knowledge not just of changes in the mean climate, but also of changes in variability and extremes. It is important for GCM modelers, in particular, to analyze how higher moment statistics change with various CO_2 increase scenarios and why.

Another dominant theme of this session, also related to assessment of climatic impacts, is the need to examine the transient response of the climate system to external forcings like CO_2 buildup. For example, M. Schlesinger, Y. Han, and Gates surveyed how the e-folding response time of the surface temperatures have varied from about 10 to about 100 years in various studies, depending on both the sensitivity of the atmospheric model and the mixing parameters used in the ocean model. A lively discussion followed over whether eddy diffusion of heat in the ocean can be estimated based on observations based on eddy diffusion of a passive tracer such as tritium. Because both the step-function response time of a model and the lag between CO_2 build up and surface temperature increase will depend internally on the physical form of mixing parameterizations chosen (and the numerical values of the parameters), it was generally agreed that study of the transient response of a hierarchy of coupled atmosphere/ocean models is a major priority for research on the sensitivity of the climate to CO_2 increases. The outcome of such research should help markedly in the problem of CO_2-induced signal detection, as will improved analyses of data sets that contain surface temperature records for both land and oceanic sectors.

Session 8: Projecting Future Climatic Change (G. North and R. Chen, co-chairs)

The last session of the conference was devoted to the problems of forecasting climatic change for the next century. Papers by A. Owens, C. Hales and D. Wuebbles and by G. Molnar, W.-C. Wang, M. Ko and N. Sze suggested that projected increases in the concentration of trace gases in the atmosphere could nearly double the radiative "greenhouse effect" of climatic warming from CO_2 expected during the next century. The possibility of inferring local effects of climatic warming from analogs from reconstructed climates of 4500 to 8000 years ago was pursued by W. Kellogg, and from instrumental records of the past century in the western United States by P. Kay, E. Law and J. Warren.

Papers by S. Schneider, T.M.L. Wigley and M. Schlesinger, and D. Harvey described a variety of ways in which the thermal inertia of the oceans could alter the climatic response to increasing carbon dioxide concentrations. The transient response characteristics of models depend a great deal on the way heat transfer to the deep oceans is treated in the models, and how best to do this seemed to be a source of much friendly discussion among the participants at the conference. What seemed possible to conclude was that the derived estimates of the ocean lag time depended strongly on the model that was used to derive them and that, since all such models are now highly simplified, much more work is needed.

SUMMARY

The many papers and the large number of attendees generated active discussion in the sessions and at rump sessions that extended even into Friday evening. While there was a sense that progress was being made in addressing the questions that had provided the basis for the various sessions, none of the questions is yet completely answered. Important uncertainties concerning past and future climate remain. The agreement among attendees about how to proceed seemed to focus primarily on what needs to be done to further improve understanding. Suggested research directions include:

1. Consolidate and homogenize land and marine data bases;
2. Conduct detailed spatial and temporal analyses of the improving climatic record;
3. Determine whether the primary climatic effect of volcanic aerosol injections occurs within months or is spread out over a few years (or both);
4. Continue to improve model representations of processes such as clouds, radiation, and atmosphere-surface interactions;
5. Use seasonal variations, El Niño/Southern Oscillation, and other climatic fluctuations to test climate models;
6. Include interactive oceans in climate model simulations;
7. Consider the potential effects of increases in trace gas concentrations in making projections of future climate.

And most clearly, understanding the causes of past climate variations and projecting future changes is a field of atmospheric sciences where much as been accomplished and in which many opportunities exist for fruitful and important research.

KUDOS

The AMS has been endeavoring to encourage improvement of the quality of the presentations of their meetings. The overall quality of the presentations at the meeting and of the extended summaries was quite high. Based on discussions with several additional critics, the Program Chair selected the 20% of presentations that were judged to be of the best overall quality in terms of content, oral delivery, and visuals. On behalf of those who sat in the audience, the Program Chair wants to express special appreciation to the following speakers:

Tom Bell	Michael Black	Kenneth Bowman
Raymond Bradley	Robert Cess	John Christy
Arthur Douglas	W. Lawrence Gates	Stanley Grotch
Mick Kelly	Peter Lamb	Gerald Meehl
Sharon Nicholson	Alan Robock	Michael Schlesinger
Stephen Schneider	Richard Somerville	Kevin Trenberth

A special letter of appreciation has also been sent.

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